Renewable and Sustainable Energy Reviews 18 (2013) 144–153

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Multi-objective ranking of climate change mitigation policies and measures in Lithuania

Dalia Streimikiene [a,*], Tomas Balezentis [b]

[a] Lithuanian Energy Institute, Breslaujos 3, Kaunas, LT-44403, Lithuania
[b] Lithuanian Institute of Agrarian Economics, V. Kudirkos 18, Vilnius, LT-03105, Lithuania

ARTICLE INFO

Article history:
Received 5 August 2012
Received in revised form
25 September 2012
Accepted 30 September 2012
Available online 6 November 2012

Keywords:
Climate change
Climate change mitigation
Sustainable energy development
Climate change mitigation policy
Multi-criteria decision making
Lithuania

ABSTRACT

The aim of the article is to develop technique for climate change mitigation policies assessment based on priorities of sustainable energy development. There is a close relationship between energy policies and tools aiming at sustainable energy development targets, i.e. promotion of renewable energy sources and energy efficiency measures and climate change mitigation tools. Therefore ranking of climate change mitigation tools based on their impact sustainable energy development targets is necessary seeking to ensure harmonization of policies and their synergy effect. The main tasks of the article are: (i) to define EU sustainable energy development targets, (ii) to analyze EU energy and climate change mitigation policies and their interactions, (iii) to propose a multi-criteria framework for climate change mitigation policies assessment and ranking, and (iv) to apply multi-criteria decision making methodology for climate change mitigation policies ranking in Lithuania. The main findings of paper are related with proposed technique for climate change mitigation policies assessment and application of this technique for ranking of climate change mitigation policies in Lithuania.

Contents

1. Introduction

Energy and climate change are on top of the agenda of the European Union (EU) today. Based on the European Commission's energy policy package entitled "Energy Policy for Europe" [1], which was accompanied by a number of sectoral policies to implement the overall strategy, the Member States adopted an Energy Policy for Europe (EPE) which pursues the three objectives: increasing security of supply, ensuring the competitiveness of European economies and the availability of affordable energy and promoting environmental sustainability and combating climate change.

Therefore energy and climate change mitigation policies are designed for the implementation of concrete environmental, social or economic targets should considered in complex way by applying integrated assessment of these policy measures economic, social and environmental impact. The results of implemented policies and measures targeting sustainable energy development needs to be

* Corresponding author. Tel.: +370 37 435705; fax: +370 37 351271.
E-mail addresses: dalia@mail.lei.lt (D. Streimikiene), tomas@laei.lt (T. Balezentis).

1364-0321/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.rser.2012.09.040

monitored seeking to evaluate their efficiency in moving towards sustainable development. Another important issue is the selection of the best policies and measures and achievement of policies harmonization based on their capability to deliver to sustainable energy development future therefore sustainability monitoring or sustainability assessment is crucial in dealing with sustainable energy development.

There is a close relationship between energy policies and tools aiming at sustainable energy development targets, i.e. promotion of renewable energy sources and energy efficiency measures and climate change mitigation tools. Therefore ranking of climate change mitigation tools based on their impact sustainable energy development targets is necessary seeking to ensure harmonization of policies and their synergy effect. The main tasks of the article are

- to define EU sustainable energy development targets,
- to analyze EU energy and climate change mitigation policies and their interactions,
- to propose framework for climate change mitigation policies assessment and ranking,
- to apply climate change mitigation policies assessment technique for climate change mitigation policies ranking in Lithuania.

The main findings of this paper are related with proposed technique for climate change mitigation policies assessment and application of this technique for ranking of climate change mitigation policies in Lithuania.

The multi-criteria decision making (MCDM) methods are those suitable for providing rationale for sustainable energy policy [2–8]. One of the MCDM methods viz. the MULTIMOORA method was employed for the prioritization of sustainable energy sources [9]. This study applies the MULTIMOORA method for prioritization of the climate change mitigation strategies.

Accordingly the following chapters will develop a framework for climate change mitigation policies assessment to enhance synergies between energy, environmental and climate change mitigation policies. The system of indicators for climate change mitigation policies ranking will be proposed in terms of the EU sustainable energy development priorities. The case study for Lithuania will be presented seeking to illustrate application of developed indicators framework.

2. EU sustainable energy policy targets

In recognition of the risks and challenges to European energy supply, the Heads of State and government of the 27 Member States of the EU at the spring 2007 European Council have committed themselves to a low-carbon energy future [1]. The main aims of Energy Policy for Europe (EPE) are the following:

- increasing security of supply,
- ensuring the competitiveness of European economies and the availability of affordable energy, and
- promoting environmental sustainability and combating climate change.

In the center of the new energy policy is the EU's commitment to reduce its greenhouse gas (GHG) emissions by at least 20% by 2020 compared with 1990 levels, not least because CO_2 emissions from energy make up 80% of EU GHG emissions. By using less energy and using cleaner, locally produced energy, the EU aims to increase energy security by limiting its growing exposure to increasingly volatile prices for oil and gas, while stimulating competitiveness in the European energy market.

In general terms, the EPE is based on five pillars [10]. First, the EU aims at increasing its energy efficiency by saving 20% of its energy by 2020. This will save about 780 million tones of CO_2 from being emitted into the atmosphere. Second, the share of renewable energy sources in the total energy mix is intended to triple to 20% by 2020, while aiming for a 10% biofuel component in vehicle fuel by 2020. The third pillar focuses on reducing the carbon emissions from hydrocarbons. Of particular importance in this context is the role of coal, which is relatively cheap and available in Europe, but "dirty" in environmental terms as compared to other energy sources. The development of carbon capture and storage (CCS) technologies is thus a crucial factor in securing future energy supplies. The fourth and fifth pillars of the EPE are the EU's carbon market and an open and competitive internal energy market.

A competitive market is expected to increase security of supply by improving the conditions for investment in power plants and transmission networks, which in turn will help to avoid interruptions in power or gas supplies. To facilitate its creation, the European Commission has recently published its third legislative package including proposal for a number of measures to increase competition in the EU electricity and gas markets. These include, amongst others, the separation of production and supply from transmission networks ("unbundling"), the facilitation of cross-border energy trade, as well as greater transparency of the markets. These proposals are currently being discussed by the Member States within the Council. In the following paragraphs the main EU policy documents will be briefly reviewed.

The EU Green paper on European Strategy for Sustainable, Competitive and Secure Energy SEC (2006) 317 [11] sets the main priorities for EU energy strategy. The general EU policy objectives considered most relevant to the design of energy policy are: competitiveness of the EU economy, security of supply and environmental protection. These objectives should help to address central policy concerns such as job creation, boosting overall productivity of the EU economy, protection of the environment and climate change. Overall competition of economy is pursued by liberalizing the EU electricity and gas markets and restructuring of energy sector. For fostering competitiveness of the EU economy and concomitant income and added value creation, the promotion of one internal market at Union levels is considered essential. Cross-border trade on level playing-field terms would foster competition.

Security of supply is the priority concern of EU energy policy. The Green Paper on energy supply security COM (2000) 769 [12] states, that the EU will become increasingly dependent on external energy sources. It was stressed in this paper that the EU has very limited scope top influence energy supply conditions but it can intervene on the demand side mainly by promoting energy saving in buildings and transport sector. The EU is not in position to respond to the challenges of climate change and to meet its Kyoto protocol commitments. The Green Paper identifies two main policy priorities: controlling the growth of demand and managing supply dependency.

For the controlling of demand growth the fiscal and financial instruments should be used. Fiscal interventions in energy prices should remove distortions between alternative energy carriers and between member states and make energy prices reflect the real costs including environmental damage costs. The reduction of energy demand growth should be achieved at transportation sector and buildings through stimulation of energy-efficient technology (regulation, certification, fiscal measures and funding of R&D.

The Commission's new Green Paper on energy efficiency COM (2005) 265 [13] stress the importance of energy efficiency

improvement for the controlling of demand growth and security of supply. According to estimates, the economic potential for improving energy efficiency in 2010 for all sectors combined is 20% of the total annual primary energy consumption of the current level.

Lack of information for consumers and manufacturers, technical barriers and financial obstacles also hamper investment in energy efficiency.

In general terms, efforts must be made to promote energy efficiency in other policies, notably in regional, transport, fiscal, research and development and international cooperation policies. More specifically, the following areas for action are proposed as priorities for the short and medium term:

(1) energy efficient buildings,
(2) energy-efficient household appliances and other end-use equipment,
(3) wider use of negotiated and long-term agreements on minimum efficiency requirements,
(4) increased dissemination of information,
(5) third-party financing, guarantee of results and other creative financing schemes,
(6) energy efficiency in the electricity and gas sectors and combined heat and power (CHP),
(7) energy management and public and cooperative technology procurement.

For managing supply dependency the Green Paper on security of supply suggests the stimulation of renewables by internalization of social costs in the energy prices and strengthening of supply infrastructure networks with due regards to environmental impacts. Green Paper on energy security emphasizes the role of technology development. Technology may contribute to increase of energy efficiency, to achieving security of supply and reduction of GHG emissions, in particular by improving access to indigenous energy resources in particular renewable energy resources. The state aid is foreseen for promoting the use of RES and combined heat and power production by way of tax exemptions or reductions.

The White Paper on renewable sources White Paper for a Community Strategy and Action Plan on renewable energy sources COM (97) 599 final [14] states that member states should formulate indicative targets contribute to the ambitious indicative target of doubling the overall share of RES in the EU by 2010. It sets an indicative target of 12% for the contribution by RES to the total primary energy consumption within EU by 2010 and contains a strategy and action plan to achieve this target. Pursuant to the White paper on Renewables the Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market (hereafter called the *RES-E Directive*) was passed in 2001 [15]. It adds the indicative target contribution of 22.1% by renewables-based electricity to total EU electricity consumption in year 2010.

2003/30/EC Directive [16] on the promotion of the use of biofuels or other renewable fuels in transport (RF Directive) sets that Member States must ensure by end of 2005 a 2% minimum proportion of biofuels of all gasoline and diesel fuels sold on their market. In longer term the target is to achieve a share of 5.75% of biofuels for transport in the total amount of fuels in Europe by 2010 and 20% by 2020.

2002/91/EC Directive [17] on the energy performance of buildings sets target to realize a savings potential of around 22% by 2010 for energy used in heating, air-conditioning, hot water and lighting.

2004/8/EC Directive [18] on the promotion of cogeneration based on a useful heat demand in the internal energy market aims to increase energy efficiency and improve security of supply by creating a framework for promotion and development of high efficiency cogeneration of heat and power based on useful heat demand and primary energy savings taking into account the specific national circumstances especially climate and economic conditions.

All these directives have positive impact on GHG emission reduction and achieving of Kyoto target. EU has ratified Kyoto Protocol committing itself to 8% GHG emission reduction in the period 2008–2012 from the 1990 and took new obligations for 2020. Equally the New Member States are determined to meet their individual targets under the Kyoto Protocol. Therefore the GHG emission reduction in energy sector is the priority issue in EU energy policy.

In March 2000 the Commission launched the European Climate Change Programme (ECCP) [19]. The ECCP led to the adoption of a range of new policies and measures, among which the EU's emissions trading scheme, which will start its operation on 1 January 2005, will play a key role. As a result of the EU's and individual Member States actions, the latest monitoring data indicates that the European Union has delivered on its long-standing commitment to stabilize emissions of CO_2 at the level of 1990 in the year 2000. The EU-15 is committed to deliver the collective 8% cut in emissions by 2008–2012 to which it is signed up under the Kyoto Protocol. The monitoring mechanism and its review, as well as the EU's emissions trading scheme and the link with the Kyoto flexible mechanisms (JI and CDM) are key elements of the EU's climate change strategy.

The Green Paper on greenhouse gas emissions trading within the European Union COM (2000) 87 [20] sets the main blueprints for the introduction of GHG emission trading scheme in EU. In January 2005 the European Union Greenhouse Gas Emission Trading Scheme (EU ETS) commenced operation as the largest multi-country, multi-sector Greenhouse Gas emission trading scheme world-wide. The scheme is based on Directive 2003/87/EC, which entered into force on 25th October, 2003.

During the first phase of the ECCP1 (European Climate Change Programme, concluded in June 2001) the idea of a Directive promoting the use of heat from renewable energy sources was put forward. This legislation would complement other types of actions mentioned in the Commission's 1997 White Paper on renewable sources of energy and it would be modeled on the format of the RES-E directive, i.e. covering targets, support schemes, certification, easier administrative procedures, etc. for heat from biomass (e.g. local space-/hot water heating, CHP and distributed heat, district heating), active solar systems (e.g. local space/hot water heating), geothermal sources (including heat pumps).

Therefore the main targets of EU energy policy are: increase of energy security, opening of energy markets, promotion of renewables and cogeneration, increase of energy efficiency and reduction of impact on environment.

3. Indicator framework for climate change mitigation policy assessment

Achieving requirements of EU directives targeting sustainable energy development requires regular monitoring of impacts of selected policies and strategies to see if they are furthering sustainable development or if they should be adjusted [21]. It is important to be able to measure a country's state of implementation of EU directives aiming at sustainable development and to monitor its progress or lack of progress towards achievement of the main targets set by these directives. First of all it is necessary to know the country's current status concerning the established

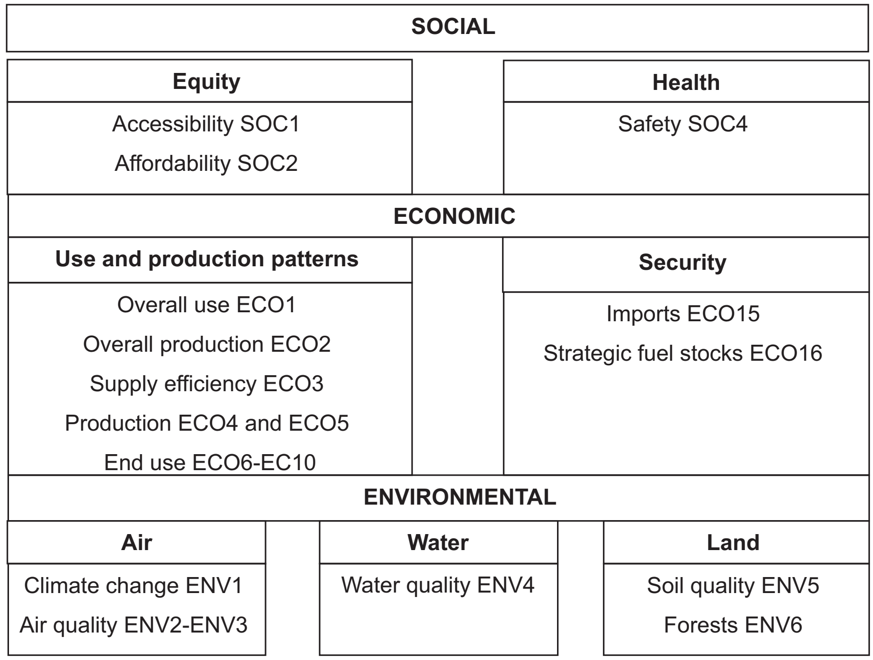

Fig. 1. EISD indicators set.

targets, what needs to be improved and how these improvements can be achieved. Second, it is very important for policy makers to understand the implications of selected directives, energy, environmental and economic programmes, policies and plans and their impacts on achieving the main targets and goals set by the main directives. Therefore choosing energy fuels and associated technologies for the production, delivery and use of energy services, it is essential to take into account economic, social and environmental consequences. Policy makers need simple methods for measuring and assessing the current and future effects of energy use. For this purpose energy indicator establishing the aforementioned targets can be used. There are several frameworks of indicators developed to assess the trends toward sustainable development. The Energy Indicators for Sustainable Development (EISD) have been developed by International Atomic Energy Agency (IAEA).

The EISD is an analytical tool developed which can help energy decision- and policy-makers at all levels to incorporate the concept of sustainable development into energy policy. The EISD set is used to present energy, economic, environmental and social data for policy makers in a coherent and consistent form, showing their linkages and their usefulness for making comparisons, trend analyses and policy assessments. Some indicators from EISD set can be selected and applied for the analysis of the EU energy policies in Member States and for the assessing their success towards implementation of the main targets set by directives and other policies establishing goals for energy efficiency improvements, use of renewables and greenhouse gas emission reduction. Therefore indicators relevant to EU energy policies will be selected from the EISD list. The additional indicators to define targets established by EU policies will be developed as well. EISD core set is organized following the conceptual framework used by United Nations Commission on Sustainable Development. There are 30 indicators, classified into three dimensions: social, economic and environmental. The scheme of core EISD is presented in Fig. 1.

Trends in overall energy productivity, supply efficiency, end-use productivity, and fuel mix and energy security will be analyzed using economic dimension indicators. Climate change mitigation issues will be addressed by environmental dimension indicators.

The appropriate EISD were selected to address requirements of EU directives targeting security of supply (ECO 15), energy efficiency improvements (ECO 2), promotion of renewables (ECO 11, ECO 13) and greenhouse gas (ENV1) and other atmospheric pollutants emissions (ENV2). The selected indicators were grouped by 4 priority areas established by EU energy policy: increase of energy efficiency, use of renewables, increase of energy security and greenhouse gas and other atmospheric emission reduction. Additional to EISD framework indicators were developed to address targets of EU relevant to energy efficiency and renewables. The indicators framework for EU energy policy analysis and monitoring of targets by EU directives are presented in Table 1.

All these EU energy policy indicators can be connected to each other via the chain of mutual impacts seeking to develop comprehensive policy framework for monitoring implementation of EU directives and tracking various interacting policy measures targeting relevant indicators. The last indicator in EU energy policy indicators framework is greenhouse gas emission indicator as all other EU policies (targeting energy efficiency improvements, promotion of renewables, and increase in energy supply security) in the end have positive impact on greenhouse gas emission reduction [22].

4. Development of energy scenarios for climate change mitigation policies and measures assessment

Seeking to harmonize environmental and energy policies the ranking of climate change mitigation policies needs to be performed based on priorities of sustainable energy development. Such ranking would allow selecting the best policies from the point of view of sustainable energy development targets. Therefore it is important to select policies evaluation criteria for climate change mitigation policies assessment based on the priority objects of energy policy; and to use a system of indicators, covering the basic criteria.

Table 1
Indicators selected for EU energy policy analysis.

Indicators	Acronym	Subtheme	Directive or policy document	Target	Date for achievement
			Energy efficiency (EE)		
End-use energy intensity of GDP	EE1 (ECO 2)	Energy efficiency	Directive 2006/32/EC on end-use efficiency and energy services	To reduce by 9°% the current level (2006)	2016
Energy saved in buildings	EE2	Energy efficiency	2002/91/EC Directive on the energy performance of buildings	22% of energy used in buildings	2010
Savings of primary energy supply	EE3	Energy efficiency	The Commission's new Green Paper on energy efficiency COM (2005) 265	20% from year 2005 level	2020
The share of CHP in electricity production	EE4	Energy efficiency	2004/8/EC Directive on the promotion of cogeneration national energy strategy	Double the current share	2010
			Use of renewables (RES)		
The share of renewables in primary energy supply	RES1 (ECO 13)	Renewables	The white paper on renewable sources	12%	2010
The share of renewables in electricity generation	RES2 (ECO 11)	Renewables	Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market	22.1% (7% for Lithuania)	2010
The share of renewables in heat production	RES3	Renewables	Proposal for directive promoting the renewable heating and cooling	25%	2020
The share of renewables in fuel used in transport	RES4	Renewables	2003/30/EC directive on the promotion of the use of biofuels or other renewable fuels in transport	2% 5.75% 20%	2005 2010 2020
The share of renewables in final energy	RES5	Renewables	EU energy and climate packageCOM(2008) 30 final	20%	2020
			Security of supply (SS)		
Energy independency	ES1 (ECO15)	Security of supply	The EU Green paper on European strategy for sustainable, competitive and secure energy	50 %	2030
			Atmospheric pollution reduction		
Greenhouse gas emissions (CO_2 emissions from energy sector)	GHG1 (ENV1)	Climate change	Kyoto protocol	Reduction by 8% of year 1990 level	2008–2012
				Reduction by 20% of year 1990 level	2020
SO_2 emissions, NO_x emissions, VOC emissions, NH3 emissions SO_2 emissions, NO_x emissions, VOC emissions, NH_3 emissions	ACD (1–5) (ENV2)	Acidification and eutrophication	Gothenburg protocol NEC directive 2001/81EC	Reduction by 35%, 30%, 11% and 0% comparing to 1990 level. Reduction by 87%, by 50%, by 46°% and by 41% compared to 2000 level	2010 2020

Table 2
Climate change mitigation scenarios.

Version	Trading in emission allowances, or CO_2 tax since 2005, EUR/t	The fixed electricity price or the green certificate rate since 2005, EUR/kWh
Basic version "With measures"	10	0.06
A1 version	0	0.06
A2 version	13.5	0.06
A3 version	10	0.2
A4 version	10	0
A5 version "With the new measures"	13.5	0.2
A6 version "Without measures"	0	0

In the second step a multi-criteria decision analysis of climate change mitigation measures will be performed, which in turn consists of 2 steps: (1) the evaluation of climate change mitigation measures influence on energy policy priorities presented in Table 2 by applying mathematical models; (2) the assessment and ranking of climate change mitigation options or their packages according to the main criteria established based on energy policy priorities by applying MCDA analysis.

Applying the "MESSAGE" model, we can evaluate the impact of the climate change mitigation measures for the reduction of greenhouse gas emissions in the fuel combustion sector. In addition, applying the greenhouse gas emissions forecasting models, we can evaluate the economic efficiency of the climate change mitigation measures, i.e. can be identified measures which ensure maximum reduction of the greenhouse gas with the minimum costs.

Another major issue is related to the impact of the climate change mitigation measures to other important objectives of sustainable development, such as increase of energy efficiency, promotion of renewable energy resources, reduction of other atmospheric pollutants' emissions, because the measures of climate change mitigation have an influence for these purposes. The proposed evaluation methodology of the climate change mitigation measures impact in the energy sector is based on the evaluation of the climate change mitigation measures impact for the main objectives of sustainable energy development.

Climate change mitigation measures effect to the objectives of sustainable energy development is determined by the formation of scenarios of the climate change mitigation for the MESSAGE model (see Table 2).

As one can see from information provided in Table 2 the following scenarios were developed for assessment of climate change mitigation policies and measures in Lithuania:

- Basic scenario or scenario with measures includes EU GHG emission trading scheme with low price for CO_2 emission allowance and current low Feed-in price for electricity produced by renewables. The average Feed-in tariff is being applied by formulating scenario.
- The A1 scenario includes just current Feed-in price for electricity produced from renewable energy sources.
- A2 scenario includes GHG emission trading scheme assuming higher price for CO_2 allowance trading and current Feed-in price for electricity produced from renewable energy sources.
- A3 scenario includes EU GHG emission trading scheme with low price for CO_2 emission allowance and Green certificate trading with average price of green certificate—0.2 EUR/kWh.
- A4 scenario includes just EU GHG emission trading scheme with low price for CO_2 emission allowance.
- A5 scenario with additional measures includes EU GHG emission trading scheme with high price for CO_2 emission allowance and Green certificate trading with average price of green certificate – 0.2 EUR/kWh
- A6 scenario is scenario without measures and do not include any climate change mitigation measures.

In the following step the impact of climate change mitigation measures on Lithuania energy policy priorities presented in Table 1 will be assessed by applying energy optimization modeling.

5. The impact of climate change mitigation measures on priorities of energy policy in Lithuania

The developed scenarios reflect not only the classic scenario of climate change policy ("with measures", "without measures" and "with the new measures"), but also various combinations of the climate change mitigation measures, including the main flexible climate change mitigation tools. The various scenario run by applying energy optimization model Message allows to define the least-cost energy sector development solution and to assess the impact of the climate change mitigation measures on GHG emission reduction, energy intensity, share of renewables in electricity generation and final energy consumption and the system costs. Summarized data of scenarios and their impact on sustainable energy development objectives is presented in the Table 3.

In order to select the best climate change mitigation measure or their combination, it is necessary to perform a multi-criteria decision making analysis.

6. MCDA analysis and ranking of climate change mitigation measures in Lithuania

6.1. The MULTIMOORA method

The MULTIMOORA method begins with a response matrix X where its elements x_{ij} denote i^{th} alternative of j^{th} objective ($i=1,2,\ldots,m$and $j=1,2,\ldots,n$). The method consists of three parts, viz. the Ratio System, the Reference Point approach, and the Full Multiplicative Form. The former two parts were originally introduced by Brauers and Zavadskas [23] as the Multi-Objective Optimization by Ratio Analysis (MOORA).

The Ratio System of MOORA. Ratio system employs the vector data normalization by comparing alternative of an objective to all values of the objective

$$x_{ij}^{*} = w_j \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{1}$$

where x_{ij}^{*} denotes i^{th} alternative of j^{th} objective and w_j is weight of the j^{th} criterion, $\sum_j w_j = 1$. In the absence of negative values, these numbers belong to the interval [0;1]. These indicators are added (if desirable value of indicator is maximum) or subtracted (if desirable value is minimum). Thus, the summarizing index of each alternative is derived in this way

$$y_i^{*} = \sum_{j=1}^{g} x_{ij}^{*} - \sum_{j=g+1}^{n} x_{ij}^{*} \tag{2}$$

where $g=1,2,\ldots,n$ denotes number of objectives to be maximized. Then every ratio is given the rank: the higher the index, the higher the rank.

The Reference Point of MOORA. Reference point approach is based on the Ratio System. The Maximal Objective Reference Point (vector) is found according to ratios found in Eq. 1. The j^{th}

Table 3
Climate change mitigation scenarios and their impact in terms of sustainable energy development objectives.

Tasks and measures	Basic	A1	A2	A3	A4	A5	A6
To reduce primary energy intensity by 50% in 2020 comparing with 2002(energy intensity in GWh/mio Lt)	0.39	0.44	0.38	0.38	0.39	0.38	0.44
To save 20% of primary energy in 2020 comparing with 2005 (primary energy supply in GWh)	51,552	57,516	50,032	51,552	51,553	5003	57,517
Share of CHP in the structure of electricity production is 35% (2025) (in %)	22	29	27	27	27	26	29
The share of RES in 2025 in primary energy is 20% (in %)	27	25	28	27	27	28	25
The share of RES in final energy in 2020 is 23% (in %)	18	18	18	18	18	18	18
To reduce CO_2 emissions in 2008–2012 by 8% comparing with 1990 (CO_2 emission Mt)	4.96	5.29	3.61	4.94	4.94	3.61	5.39
To reduce CO_2 emissions in 2020 by 20% comparing with 1990 (CO_2 emission Mt)	4.91	6.8	4.8	4.9	4.9	4.8	6.8
To reduce SO_2 emissions in 2020 by 82% comparing with 2000 (SO_2 emissionsthousand t)	22.9	22.1	22.1	22.0	22.1	22.0	22.1
To reduce NO_x emissions in 2020 by 60% comparing with 2000 (NO_x emissions thousand t)	10.44	15.2	10.23	10.45	10.45	10.2	15.2
Total costs of the system, Million EUR	5584	6560	5398	5522	5581	5460	6600

Table 4
The initial decision matrix.

Policies	Energy intensity (GWh/million Lt)	Primary energy supply (GWh)	Share of CHP in the structure of electricity production (%)	The share of RES in primary energy (%)	CO_2 emissions in 2010–2012 (Mt)	CO_2 emission in 2020 (Mt)	SO_2 emission in 2020 (thousand t)	NO_x emission in 2020 (thousand t)	Total costs of the system (million EUR)
	1	2	3	4	5	6	7	8	9
	MIN	MIN	MAX	MAX	MIN	MIN	MIN	MIN	MIN
Basic	0.39	51,552	22	27	4.96	4.91	22.9	10.44	5584
A1	0.44	57,516	29	25	5.29	6.8	22.1	15.2	6560
A2	0.38	50,032	27	28	3.61	4.8	22.1	10.23	5398
A3	0.38	51,552	27	27	4.94	4.9	22	10.45	5522
A4	0.39	51,553	27	27	4.94	4.9	22.1	10.45	5581
A5	0.38	5003	26	28	3.61	4.8	22	10.2	5460
A6	0.44	57,517	29	25	5.39	6.8	22.1	15.2	6600

coordinate of the reference point can be described as $r_j = \max_i x^*_{ij}$ in case of maximization. Every coordinate of this vector represents maximum or minimum of certain objective (indicator). Then every element of the normalized response matrix is recalculated and final rank is given according to deviation from the reference point and the Min–Max Metric of Tchebycheff:

$$\min_i \left(\max_j \left| r_j - x^*_{ij} \right| \right). \tag{3}$$

The Full Multiplicative Form and MULTIMOORA. Brauers and Zavadskas [24] proposed MOORA to be updated by the Full Multiplicative Form method embodying maximization as well as minimization of purely multiplicative utility function. Overall utility of the i^{th} alternative can be expressed as dimensionless number

$$U'_i = \frac{A_i}{B_i} \tag{4}$$

where $A_i = \prod_{j=1}^{g} (x_{ij})^{w_j}$ denotes the product of objectives of the i^{th} alternative to be maximized with $g = 1, \cdots, n$ being the number of objectives to be maximized andwhere $B_i = \prod_{j=g+1}^{n} (x_{ij})^{w_j}$ denotes the product of objectives of the i^{th} alternative to be minimized with $n-g$ being the number of objectives (indicators) to be minimized. Thus MULTIMOORA summarizes MOORA (i.e. Ratio System and Reference point) and the Full Multiplicative Form. Brauers and Zavadskas [25] proposed the dominance theory to summarize the three ranks provided by different parts of MULTIMOORA.

Absolute Dominance means that an alternative, solution or project is dominating in ranking all other alternatives, solutions or projects which are all being dominated. This absolute dominance shows as rankings for MULTIMOORA: $(1-1-1)$. *General Dominance in two of the three methods* is of the form with $a < b < c < d$

(d–a–a) is generally dominating (c–b–b);
(a–d–a) is generally dominating (b–c–b);
(a–a–d) is generally dominating (b–b–c);

and further transitiveness plays fully.

Transitiveness. If *a* dominates *b* and *b* dominates *c* than also *a* will dominate *c*. *Overall Dominance of one alternative on the next one.* For instance (a–a–a) is overall dominating (b–b–b) which is overall being dominated, with (b–b–b) following immediately (a–a–a) in rank (transitiveness is not playing). *Absolute Equability* has the form**:** for instance (e–e–e) for 2 alternatives. *Partial Equability* of 2 on 3 exists e. g. (5–e–7) and (6–e–3). Despite all distinctions in classification some contradictions remain possible in a kind of *Circular Reasoning*. We can cite the case of

Object A (11–20–14) $\succ$ Object B. (14–16–15);
Object B (14–16–15) $\succ$ Object C (15–19–12); but
Object C (15–19–12) $\succ$ Object A (11–20–14).

Here, the operator $\succ$ represents a General Dominance. In such a case the same ranking is given to the three objects.

6.2. *The MCDM procedure for assessment of the policy scenarios*

The MCDM procedure consists of the following stages: selection of the criteria and directions of optimization thereof, definition of the alternatives, and data aggregation. Table 3 presented the initial set of objectives and respective criteria. As one can note, the objective regarding the share of RES in final energy in

Table 5
The normalized decision matrix, ratio system, and Maximal Objective Reference Point (MORP).

	1	2	3	4	5	6	7	8	9	y_i^*	Rank
Basic	0.395	0.429	0.326	0.413	0.432	0.359	0.424	0.350	0.388	-2.038	5
A1	0.446	0.478	0.430	0.382	0.461	0.498	0.409	0.510	0.456	-2.445	6
A2	0.385	0.416	0.400	0.428	0.314	0.351	0.409	0.343	0.375	-1.765	2
A3	0.385	0.429	0.400	0.413	0.430	0.359	0.407	0.350	0.384	-1.931	3
A4	0.395	0.429	0.400	0.413	0.430	0.359	0.409	0.350	0.388	-1.947	4
A5	0.385	0.042	0.386	0.428	0.314	0.351	0.407	0.342	0.379	-1.407	1
A6	0.446	0.478	0.430	0.382	0.469	0.498	0.409	0.510	0.459	-2.456	7
MORP	0.385	0.042	0.430	0.428	0.314	0.351	0.407	0.342	0.375		

Table 6
Reference point approach.

	1	2	3	4	5	6	7	8	9	$\max_j \lvert r_j - x_{ij}^* \rvert$	Rank
Basic	0.010	0.387	0.104	0.015	0.118	0.008	0.017	0.008	0.013	0.387	3
A1	0.061	0.437	0.000	0.046	0.146	0.146	0.002	0.168	0.081	0.437	6
A2	0.000	0.374	0.030	0.000	0.000	0.000	0.002	0.001	0.000	0.374	2
A3	0.000	0.387	0.030	0.015	0.116	0.007	0.000	0.008	0.009	0.387	3
A4	0.010	0.387	0.030	0.015	0.116	0.007	0.002	0.008	0.013	0.387	5
A5	0.000	0.000	0.044	0.000	0.000	0.000	0.000	0.000	0.004	0.044	1
A6	0.061	0.437	0.000	0.046	0.155	0.146	0.002	0.168	0.084	0.437	7

2020 was attributed with uniform values across the analyzed alternatives of climate change mitigation policies. Therefore we have dropped the latter objective from the further analysis. Table 4 therefore presents the resulting decision matrix containing nine criteria and seven alternatives (i. e. GHG emission mitigation policies).

In order to facilitate the MCDM procedure, the initial decision matrix was normalized by employing Eq. 1. Noteworthy, we considered every criterion as being an equally important one and therefore omitted the weight vector. The normalized decision matrix is given in Table 5. The alternatives were ranked in the spirit of the Ratio System by the virtue of Eq. (2). These ranks are also reported in Table 5. Scenarios A5, A2, and A3 are the most preferable ones, in that order. Meanwhile, Scenario A6 was attributed with the lowest rank. The last row in Table 5 presents the Maximal Objective Reference Point (MORP) which constitutes a yardstick for the multi-criteria comparison of the alternatives.

The Reference Point approach was further facilitated as defined in Eq. (3). The following Table 6 presents the Tchebycheff distances of alternative from the MORP. As in case of the Ratio System, the Reference Point approach identified Scenario A5 as the most preferred alternative, whereas Scenario A6 remained at the very bottom of the ranking.

Finally, Eq. (4) was employed to rank the policies according to the Full Multiplicative Form (Table 7). Again, Scenario A5 was the most preferable and Scenario A6 remained at the other end of spectrum.

The three ranks provided for climate change mitigation scenarios by different parts of MULTIMOORA are reported in Table 8. As one can note, the results are quite robust with little discrepancy in the Reference Point approach where the Basic scenario and Scenario A3 share the ranks of 3–4.

To conclude, Scenario A5 was chosen as the most sustainable alternative in terms of multiple ecological and economic objectives, whereas Scenarios A2 and A3 were the second and third best options, respectively. The application of MULTIMOORA therefore enabled to tackle the trade-offs between multiple objectives and to select the best option of climate change mitigation packages.

Table 7
The full multiplicative form.

Alternatives	U_i'	Rank
Basic	9.09E-10	5
A1	3.61E-10	6
A2	1.88E-09	2
A3	1.21E-09	3
A4	1.16E-09	4
A5	1.8E-08	1
A6	3.53E-10	7

Table 8
The final ranking of the strategies for climate change mitigation.

	Ratio system	Reference point	Multiplicative form	Final rank (MULTIMOORA)
Basic	5	3	5	5
A1	6	6	6	6
A2	2	2	2	2
A3	3	3	3	3
A4	4	5	4	4
A5	1	1	1	1
A6	7	7	7	7

There are many studies dealing with assessment of energy options and using various MCDA techniques however there are just several papers dealing with multi-criteria assessment of environmental or climate change mitigation tools. Streimikiene et al. [26] presented the multi-criteria model for assessment of electricity generation technologies and defined that renewable energy technologies are the most sustainable one. Other authors such as Kaya and Kahraman [27] applied modified fuzzy TOPSIS methodology for the selection of the best energy technology alternative and identified that biomass is the best technology in terms of achievement of economic, social and environmental goals. Yang and Chen [28] applied the TOPIS method for evaluation of alternative electricity supply strategies. Afgan and

Carvalho [29] applied multi-criteria analysis for ranking of electricity generation plants by developing General Index of Sustainability. The renewable energy technologies received the highest ranking in accordance with General Index of Sustainability. Becalli et al. [30] applied multi-criteria assessment of renewable energy generation options. Other studies also tried to assess the economic, social and environmental indicators and trade-off between them in ranking energy generation options however there are no studies in Lithuania dealing with multi-criteria assessment of climate change mitigation tools. Streimikiene et al. [31] and Roos et al. [32] have evaluated the impact of international climate change mitigation regimes on feasibility to implement EU Energy and Climate Change Package in European Union. The obtained results in ranking of climate change mitigation tools packages in Lithuania can provide for decision making support in Lithuanian energy and climate change mitigation policy.

7. Conclusions

Climate change mitigation measures were evaluated on a basis of the indicator system reflecting the objectives of sustainable energy development. This system was developed in accordance with the requirements stipulated by the EU directives for energy efficiency increase and promotion of renewable energy sources. Therefore it allows the national climate change mitigation policy to be integrated into the EU policy and thus result in the synergistic effect of the implemented climate change mitigation and energy policy measures.

Using the methodology, based on the influence of climate change mitigation measures to the essential objectives of sustainable energy development, there were seven scenarios of climate change mitigation measures defined. These scenarios reflect not only the classic scenarios of climate change policy, but also various combinations of the climate change mitigation measures, including the main market based instruments.

The Message model was employed for Lithuania, to evaluate scenarios of the climate change mitigation based on their influence to sustainable energy development objectives. These objectives are set for a specific date. The specific indicators of sustainable energy development were estimated for all scenarios.

After evaluating the effect of individual climate change mitigation measure to the GHG emissions reduction, it was found out that the fixed electricity price from the RES allow to reduce GHG emissions only 0.002 Mt in 2012, and the price is not fixed for the impact of GHG emissions reduction in 2020. Meanwhile, the trade in emission allowances allows reducing GHG emissions 0.45 Mt to 2012 and 1.9 Mt to 2020. Thus, the trade in emission allowances outweighs the fixed price effect and thus results in reduction in GHG emission.

The multi-criteria decision making method MULTIMOORA was employed in order to facilitate multi-objective comparison and thus identify the most compromise policy tool. Generally, the indicator set encompasses energy generation indicators, emission indicators, and costs. The three scenarios were identified as the most prospective ones, in that order

- scenario A5 includes EU GHG emission trading scheme with high price for CO_2 emission allowance and Green certificate trading with average price of green certificate – 0.2EUR/kWh;
- scenario A2 includes GHG emission trading scheme assuming higher price for CO_2 allowance trading and current Feed-in price for electricity produced from renewable energy sources;
- Scenario A3 includes EU GHG emission trading scheme with low price for CO_2 emission allowance and Green certificate trading with average price of green certificate – 0.2EUR/kWh.

The best climate change mitigation policy tools package in Lithuania in terms of achieving sustainable energy development targets in Lithuania is package including EU GHG emission trading scheme with higher than current CO_2 price and Green certificate trading scheme.

Acknowledgments

This research was funded by a grant no. (ATE 01/2011) from the Research Council of Lithuania.

References

[1] Stern N. The economics of climate change. Cabinet office—HM Treasury. Cambridge: Cambridge University Press; 2006.
[2] Pohekar SD, Ramachandran M. Application of multi-criteria decision making to sustainable energy planning—a review. Renewable and Sustainable Energy Reviews 2004;8(4):365–81.
[3] Løken E. Use of multicriteria decision analysis methods for energy planning problems. Renewable and Sustainable Energy Reviews 2007;11:1584–95.
[4] Wang JJ, Jing YY, Zhang CF, Zhao JH. Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renewable and Sustainable Energy Reviews 2009;13(9):2263–78.
[5] Heo E, Kim J, Boo KJ. Analysis of the assessment factors for renewable energy dissemination program evaluation using fuzzy AHP. Renewable and Sustainable Energy Reviews 2010;14(8):2214–20.
[6] Baños R, Manzano-Agugliaro F, Montoya FG, Gil C, Alcayde A, Gómez J. Optimization methods applied to renewable and sustainable energy: a review. Renewable and Sustainable Energy Reviews 2011;15(4):1753–66.
[7] Lee SC, Shih LH. Enhancing renewable and sustainable energy development based on an options-based policy evaluation framework: case study of wind energy technology in Taiwan. Renewable and Sustainable Energy Reviews 2011;15(5):2185–98.
[8] Yi SK, Sin HY, Heo E. Selecting sustainable renewable energy source for energy assistance to North Korea. Renewable and Sustainable Energy Reviews 2011;15(1):554–63.
[9] Streimikiene D, Balezentis T, Krisciukaitienė I, Balezentis A. Prioritizing sustainable electricity production technologies: MCDM approach. Renewable and Sustainable Energy Reviews 2012;16(5):3302–11.
[10] Nordhaus WD, Boyer JG. Warming the world: economic models of global warming. Cambridge: MIT Press; 2000.
[11] European Union (EU), Green paper on an energy strategy for sustainable, competitive and secure energy COM (2006) 0105, Brussels, 2006.
[12] European Union (EU), COM (2000) 769: Green Paper: Towards a European strategy for the security of energy supply, Brussels, 2000.
[13] European Union (EU), Green Paper on Energy Efficiency or Doing More with Less, COM, 265 final, Brussels, 2005.
[14] European Union (EU), Energy for the Future: Renewable Sources of Energy. White paper for a Community Strategy and action Plan, COM (97) 599 final, Brussels, 1997.
[15] European Union (EU), Directive 2001/77/EC of the European Parliament and of on the promotion of electricity produced from renewable energy sources in the internal electricity market, Brussels, 2001.
[16] European Union (EU), Directive 2003/30/EC of the European Parliament and of the Council of 8 May 2003 on the promotion of the use of biofuels or other renewable fuels for transport, Brussels, 2003.
[17] European Union (EU), COM 2002/91/EC: Directive on the Energy Performance of Buildings, Brussels, 2002.
[18] European Union (EU), COM 2004/8/EC: Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market, Brussels, 2004.
[19] European Commission, European Climate Change Programme, EU Action against Climate Change, 2006.
[20] European Union (EU), The Green Paper on greenhouse gas emissions trading within the European Union COM (2000) 87 2000.
[21] Faure M, Skogh G. The economic analysis of environmental policy and law.An introduction. Cheltenham: Edward Elgar; 2003.
[22] Štreimikienė D, Šivickas G. New eco-efficiency concepts and their challenges for Lithuania. Economy and Management 2008:712–7.
[23] Brauers WKM, Zavadskas EK. The MOORA method and its application to privatization in a transition economy. Control and Cybernatics 2006;35: 445–69.
[24] Brauers WKZ, Zavadskas EK. Project management by MULTIMOORA as an instrument for transition economies. Technological and Economic Development of Economy 2010;16:5–24.
[25] Brauers WKM, Zavadskas EK. MULTIMOORA optimization used to decide on a bank loan to buy property. Technological and Economic Development of Economy 2011;17:174–88.
[26] Streimikiene D, Balezentis T, Krisciukaitienė I, Balezentis A. Prioritizing sustainable electricity production technologies: MCDM approach. Renewable & Sustainable Energy Reviews 2012;16:3302–11.

[27] Kaya T, Kahraman C. Multicriteria decisionmakin in energy planning using a modified fuzzy TOPSIS methodology. Expert Systems with Applications 2011;38(6):6577–85.
[28] Yang HT, Chen SL. Incorporating a multi-criteria decision procedure into the combined dynamic programming/production simulation algorithm for generation expansion planning. IEEE Transactions on Power Systems 1989;4(1): 165–75.
[29] Afgan H, Carvalho MG. Multi-criteria assessment of new and renewable energy power plants. Energy 2002;27:739–55.
[30] Beccal M, Cellura M, Mistretta M. Decision-making in energy planning. Application of the Electre method at regional level for the diffusion of renewable energy technology. Renewable Energy 2003;28(13):2063–87.
[31] Streimikiene D. The impact of international GHG trading regimes on penetration of new energy technologies and feasibility to implement EU Energy and Climate Package targets. Renewable & Sustainable Energy Reviews 2012;16:2172–7.
[32] Roos I, Soosaar S, Volkova A, Streimikene D. Greenhouse gas emission reduction perspectives in the Baltic States in frames of EU energy and climate policy. Renewable & Sustainable Energy Reviews 2012;16:2133–46.